CHILDREN'S MOTOR LEARNING WITH AND WITHOUT VISION

BY

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THE PROBLEM

WHETHER data from the visual processes or from tactual-motor manipulation are predominant in the acquisition and performance of skilled acts has been investigated by various methods with animal and adult human subjects, but there have been few attempts to study the relationship directly in the early stages of ontogenetic development. The specific problem of this experiment is the determination of the relative effectiveness of visual versus manual cues in the motor learning of young children.

Since motor learning ordinarily consists of a series of spatial coördinations, the ultimate problem involves the relative importance of visual and tactual-motor sentienda in the organization of our spatial perceptions. The question is whether stimuli from the visual processes (including all the kinesthetic sense data from eye-movements) are in themselves sufficient and initially dominant in producing spatial ideas and appropriate motor responses, or whether the sensory receptors in the responding organ itself must give the stimulus initially. In the latter case there are two alternatives: either these spatial coördinations, learned only through manipulation, guide and educate the visual perceptions, or the two systems are entirely independent originally, and become coördinated only through their association in use.

Prior to Berkeley, vision and touch (including movement) were held to be practically interchangeable sense modes. Berkeley (1) was the first to draw a sharp distinction between the reports of the two senses, and to contend that notions of space are not intrinsic to vision, but are built up through the movement and tactual experience of the individual. This theory directed attention to the experiences of those born blind, who later gained their sight through operation. This literature has been critically reviewed by von Senden (31), who came to the conclusion that the blind have no true spatial consciousness, but that this is bound up with visual perception. None of the observations on the blind were experimentally controlled.

The difficulty in arriving at any conclusion as to the origin of space habits in normal human adults obviously lies in the fact that they are already formed long before it is possible to bring them to the laboratory. To overcome this disadvantage, some investigators have attempted to break up the habits formed and observe new ones in formation through distortion

of the visual world by means of prismatic lenses.

Stratton's (32) pioneer work with a monocular lens reinverting the retinal image led him to the conclusion that visual direction was not dependent upon tactual direction. Wooster (38), following Stratton's method, found that visual perception of the amount of error was the most helpful single factor in mastering a new space habit, and was as efficient as the tactual and kinesthetic factors combined in active touch. Ewert (11) agreed as to the primacy of visual receptors in spatially coördinated activity within the field of vision. He emphasized the typical motor learning curves of his subjects and contended that the process of reëducation after distortion of the visual field consisted simply in learning by trial and error to readjust motor behavior to new visual cues, rather than in any change in reference of the sensory data. Contrary to Wooster, however, he found that readjustment occurred where there were no overt localizing movements, although he admitted that gross adjusting movements might be replaced here by eye and head movements and by those involved in verbal activity. Finally he pointed out the influence of instruction and the ability of the human subject to inhibit sense data from receptors which might distract from the task in hand.

Recently Cutsforth (6) has demonstrated by an interesting technique the discrepancy between the visual and tactual-motor perception of spatial relationships, and the difficulties in translating tactual-motor sense data into visual terms.

Results obtained with rats have proved suggestive of problems involved in human learning. Watson (36) concluded, after extensive experiment, that the learning of rats in a maze was entirely dependent upon kinesthetic cues, each movement being the cue for the following one. Hunter (13, 14, 15, 16), Lashley and Ball (20), Dennis (8), Macfarlane (22), and Dorcus and Gray (10) have called in question the adequacy of this theory, although the rôle of vision was not specifically investigated. Perrin (23), one of the first to test blindfold human adults both with pencil and paper mazes and in an outdoor circular walking maze found that ability to run the maze developed with the ability to describe it verbally and graphically and concluded that human maze learning was perceptual and ideational rather than sensory.

Weaver and Stone (37) and Lindley (21) found that the performance of blind, anosmic, and blind-anosmic rats in a maze differed very little from that of seeing animals, but just after Watson had popularized the proprioceptive theory, Florence Richardson (30), working in his laboratory, found that blind animals were at a decided disadvantage in learning to solve certain problem box situations and to jump from one small platform to another. Subsequently Dennis (8) and Walton (34) showed that when the experimental arrangements in the maze were such that vision could be used to advantage, the animals depended predominantly upon visual cues.

All studies of the effect of vision in adult human maze learning have shown that visual aid greatly reduces errors,

especially in the initial stages of learning. Brown (2, 3) whose subjects walked through a maze made by wooden troughs laid on the floor, found that persons allowed to see the ceiling and upper part of the doors and windows learned in fewer trials than those blindfold. His findings disagreed with Perrin's, however, in that the subjects were not able to draw or describe the maze after they had learned it.

The stylus maze has been the most frequently used instrument for the study of adult learning. Carr's (4) invention of the slot maze and his elaborate studies of the effect of visual guidance by this means all confirmed the effectiveness of visual aid in motor learning for adults. Carr and Osbourn (5) found that vision during the initial trials reduced both the errors and the trials, although errors more than trials. In three of four cases, the effect was even greater during the post-visual period than during the visual. Peterson and Allison (24) achieved results similar to Carr's when the visual exposure of the maze was measured by time instead of by number of trials.

Koch and Ufkess (19) found that seeing subjects were superior to blind subjects in learning a stylus maze. This was contrary to a priori opinion, since the situation seems analogous to the usual learning methods of the blind. Moreover, those who had once had sight did better than those who had been blind from birth, the intelligence level being, of course, the same. Contrary to these results, Knotts and Miles (18), comparing the maze learning ability of blind and seeing individuals from twelve to twenty-two years of age, found the blind superior by all criteria. Examination of the authors' graphs, however, shows that the differences were very small, and the more successful learners among the blind were those whose blindness was due to accident after five years of age.

Twitmyer (33) found that subjects who casually watched another person learn a maze, without expecting to learn it themselves, did better in the early stages of learning than the blindfold subjects, though a higher efficiency was attained in less time by the blindfold practice. Time was the only criterion of learning in this study, however, and error analysis might have given different results.

The preceding studies seem definitely to establish that the adult depends to a very great extent upon visual guidance in his ordinary motor learning. But the question remains whether this is the last stage of a development which began with dominance of tactual-kinesthetic cues. The assumption has often been made that children begin with dominance of kinesthesis in the responding organ and gradually shift to visual dominance, possibly substituting the kinesthesis of eye movements, at about puberty. Investigations of sensitivity to tactual stimulation in children and adults, both blind and seeing, by Renshaw, Wherry and Newlin (26, 27) and of primitive tribes by Rivers and McDougall (see 27) have been interpreted as substantiating this theory. Inspection of the data, however, throws some doubt upon these conclusions. De Sanctis' (9) maze experiment also indicated a shift, though at a somewhat earlier age.

Rice's work with young children is

in some respects the direct antecedent of the present study. Incidental to her investigation upon "The orientation of plane figures as a factor in their perception by children," (28) she found that success in reproducing a figure, whether from the model or from memory, was more closely related to perceptual development than to motor control. This the author cites as interesting "in view of the axiom derived from the response hypothesis that accuracy of motor response is a basis for accuracy of perception and later of thought." (28 p. 141) There is the possibility of the interpretation that perceptual development is responsible for the level of motor coördination.

Rice's third study (29) was an attempt to discover and analyze eye and hand movements occurring during an act of perception. Her subjects were 10 pairs of twins between 4.6 and 7.10 years of age. After a series of initial tests in which the child's eye and hand movements were recorded while he looked at a geometrical figure and his ability to reproduce it on a blackboard was tried, one of each set of twins was given a training course. Five children watched a bright yellow knob which traveled mechanically around a diamond shaped path on a black background. The other five children followed the knob with their hands but were not allowed to see it. There were nine ten-second trials in all, three at a time one day a week. Automatograph records of the hands were taken and the eye movements photographed on the first and last trial. The control group during this period only looked at the original card representing the diamond.

The author found "no transfer effect of any kind from imposed practice of eye and hand movements on eye and hand movements of an unrestrained nature used during observation of plane figures." The synchronized records of eye and hand movements showed no relation between them, either initially or after practice. There was a practice effect in the specific activity undertaken during the practice periods, i.e. the child learned to follow the moving knob. There was also "a possible transfer effect of this practice on the rather indefinitely defined activity of drawing the figure observed." (29, p. 47) Even the last mentioned positive results are questionable. However, the interesting point for the present study is that four of the instances of possible gain were from the five children subjected to eye training, while only two were from the five given hand training.

The results of this experiment, in conjunction with the previous finding that reproduction of a figure was related to perceptual rather than motor developmental level, suggest that visual data are dominant over those from other receptors in the education of eye-hand coördinations in the young child.

II. APPARATUS

Choice of apparatus for the experiment presented difficulties for several reasons. The problem required (1) that visual and manual cues be equated in manner of application, (2) that they might be given separately, and (3) that there should be a test of their relative effect.

Rice's (29) apparatus met the requirement of separate hand and eye

training, but her method of testing by drawing the diamond introduced many new factors into the reproduction situation. As her own results showed, the ideal situation would be one in which the child was shown how to do a thing, and then asked to do exactly that thing. This ideal was not entirely realized, but a closer approach was attempted.

After some preliminary experimentation with maze patterns, a block design was selected. This was similar to Dasheill's (7) in his study of direction orientation in the rat in that it was a block pattern with no culs-de-sac other than the edges of the maze. Converted into a slot maze, similar to that designed by Carr (4) and popularized by Young (39) in the "Boy and Shoe" model, it furnished an instrument in which the child might watch a stylus travel a chosen path through the blocks, and then be asked to guide a similar stylus through the same path in an identical maze. Similarly, his hand could be guided through the path without accompanying vision, and the relative value of these two methods of guidance compared as to their effectiveness in the ability to reproduce the pattern. This study was not concerned with the relative value of guided and unguided learning, but only with the relative effectiveness of two methods of guidance.

A preliminary study with 15 children between the ages of three and five years showed that the task offered sufficient difficulty for differentiation.

While the "game" pleased most of the children at first, it soon became evident that some reward was necessary to insure continued effort. An animal cracker at the end of the test maze, concealed in a small box which opened when the child was successful, proved to be of lasting interest.

Figure 1 shows a surface view of the mazes. They were of hard wood, built up in layers. They were both 39 by 39 cm. square, with a solid border on a level with the top surface of 6 by 6 cm. blocks. The bases of the two were solid boards, 24 mm. thick.

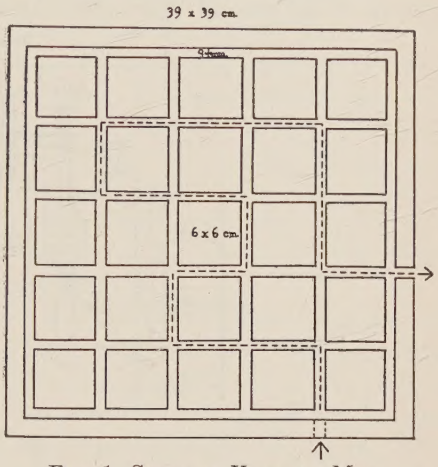


FIG. 1. SURFACE VIEW OF MAZE
The dotted line indicates the path traveled by the knob on the practice maze.

The practice maze had for its second layer two boards, 12 mm. thick, which were separated along their facing edges by 17 mm. This line of separation followed the dotted line shown in figure 1, forming the desired maze pattern. Similarly, two boards, 13 mm. thick, formed the third layer, separated along the pattern line by 9 mm. Thus the edges of this groove overhung those of the second layer 4 mm. on either side. In addition, grooves 6 mm. deep were cut in the top surface of these boards to form a block pattern. The top layer was of

blocks 13 mm. thick, carefully fitted to the surface blocks of the third layer. When complete the pattern groove was 38 mm. deep, while the depth of the remaining grooves was 19 mm. The whole was painted a rich blue, and the lighting arranged from the side so that the grooves were in shadow and the difference in depth was indistinguishable to casual examination.

The floor and sides of the wide groove in the second layer were lined with sheet tin, and a Singer sewing machine belt 8 feet long was inserted, the ends projecting through holes in the maze side at the points indicated by arrows in figure 1. The corners against which the belt rubbed were rounded and brass rollers inserted.

A stylus 69 mm. high was attached to the belt, with brass disc roller guides, 11 mm. in diameter, above and below the point of insertion. The knob of light yellowish composition was 12 mm. in diameter, 24 mm. high, and extended 31 mm. above the surface of the practice board.

In starting position, the knob stood at the edge of the board in the groove indicated by the arrow in figure 1. The end of the belt extending through the exit was hooked to a shaft revolved, through a reduction gear, by a synchronous motor, and as the belt was wound the attached knob traveled the indicated path, requiring 17 seconds to reach the exit. The mechanics are shown in figure 2. When the trip was completed, the knob was pulled back to the starting point by hand.

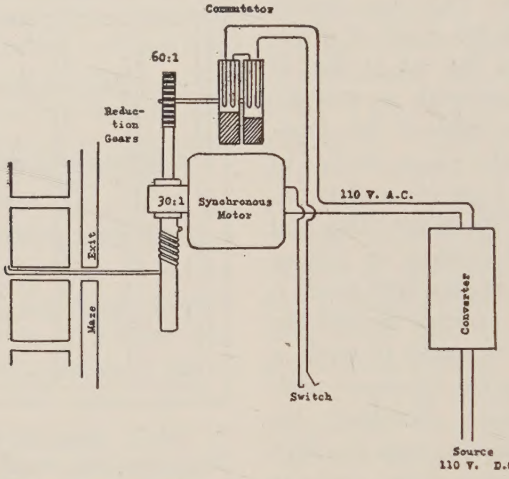


FIG. 2. DIAGRAM OF APPARATUS FOR PULLING THE STYLUS OF THE PRACTICE MAZE

The test board had only two layers of blocks, the under layer 4.4 cm. square, making the groove width at this level 25 cm. A single brass disc, 2 cm. in diameter, was attached solidly to the bottom of the stylus, which was in appearance identical with the practice maze stylus. It could be moved freely in any direction through all the grooves of the board, but could be lifted out only at the exit.

The mazes were placed side by side on tables of the same height. Each

was enclosed on three sides by beaver board 76 cm. high, painted light gray (figure 3). Flanges 12.5 cm. wide extending outward at a slight angle helped to prevent peripheral distraction of vision. Gray curtains concealed the mazes when desired.

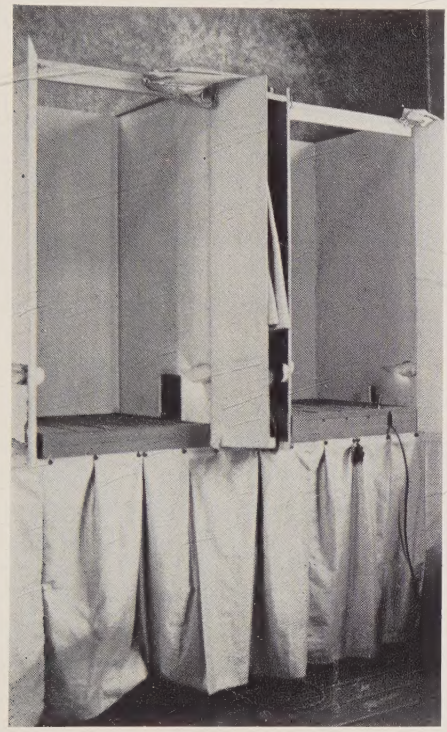


FIG. 3. MAZES READY FOR USE. PRACTICE MAZE TO THE RIGHT; TEST MAZE TO THE LEFT

A chin rest, adjustable to the height of the child, could be attached to the front of the practice maze.

Flash-light bulbs inserted in cardboard cylinders 4 cm. in diameter, with the reflector end cut slanting, were let into the beaver board at the front edges 7.5 cm. above the maze surface. These, on one circuit with 2 dry cells for the 4 lights, satisfactorily lighted the small light gray enclosure of the maze. Daylight was dimmed in the room by tan shades at the three small windows. The angle at which the lights were placed allowed the light to be reflected from the surface of the blocks without penetrating into the grooves.

At the correct exit from the test maze, an opening 15 cm. high and 12 cm. long was cut in the beaver board. Through this could be seen a small brass box, 84 by 40 mm., its top slightly above the level of the maze surface. This was wired so that when the child reached the exit by the correct route, the experimenter could touch a button which released the lid catch, allowing the lid to spring open and reveal an animal cracker within the box.

Wiring connections beneath the table were concealed by a curtain. The experimenter sat to the right of the practice maze where she manipulated the motor and the lights. During the tests she stood to the right of the child, where she could watch his performance. A drawing board was supported by the tops of the adjoining beaver board walls of the two enclosures. This held the record blanks and the button operating the cookie box.

The record blank was a reproduction of the maze with wider alleys, on which the experimenter traced the child's path in red pencil.

III. SERIES 1

A. Subjects and procedure

Fifteen children, ranging in age from thirty-five to fifty-seven months in

October, 1933, were the subjects for the first part of the experiment. They were all attending the Child Institute of the Johns Hopkins University.

The children were divided into three groups, matched for chronological age. The Intelligence Quotient for each child had been determined by the Stanford Revision of the Binet Scale, but in view of the doubtful reliability of intelligence ratings with such young children, the Intelligence Quotient was regarded less in the grouping than chronological age and observational estimates of the child's ability in his attack upon problems in his daily play life. The results seem to have confirmed the feasibility of this plan. Table 1 gives the ages and Intelligence Quotients at the beginning of the study.

TABLE 1

Age and Intelligence Quotient of subjects

GROUP I			GROUP II			GROUP III		
Child	Age	I.Q.	Child	Age	I.Q.	Child	Age	I.Q.
	months			*months*			*months*	
A	57	125	F	57	108	K	52	118
B	48	107	G	48	123	L	49	113
C	47	100	H	47	115	M	45	126
D	40	112	I	46	110	N	43	117
E	35	102	J	36	110	O	36	133
Average.....		109			113			121

The average superiority of Group III was considered no disadvantage, since the preliminary work with a similar group of children had already shown the method used with this group (mechanical guidance without vision) to be the hardest, and in view of the motor learning theories, it was planned to give this group any advantage that might accrue from superior intelligence. Preliminary work with 6 adults showed that this method presented some difficulty to them also. Only one learned after 3 demonstrations, four required 4 to 6 demonstrations, and one had not learned after 9 demonstrations.

The experimental work on the first training series continued from November 7, 1933, through February 1934. The Institute Christmas holiday includes the month of January, so that there was an unavoidable five weeks interim in the study. As will be seen later, it appeared to affect the learning very little.

Each child was given 6 practice runs and 2 tests at each period. A test followed each 3 demonstrations. If the child succeeded he was given a second test immediately, and a third if he succeeded upon that. The criterion of learning was 3 successive correct reproductions. A small amount of retracing, if his final decision was correct, was not counted against him in these tests, however. If he had not succeeded after ninety-nine to one hun-

dred and two training trials and thirty-three to thirty-four tests, the training was discontinued.

Group I—Visual and Manual Guidance

Children in Group I were allowed both to watch the knob and to grasp it lightly with the right hand as it traveled from the start to the exit. The supposition was that this combination of the two methods of tuition would prove the most effective since it seemed to duplicate the usual combination of visual and tactual-kinesthetic stimuli in the child's every-day learning of eye-hand coördinations.

Group II—Visual Guidance

Children in Group II were allowed only to watch the knob. A chin rest was adjusted to the child's height, and he was instructed to place his hands on the edge of the maze. Further attempts to control head movements seemed inadvisable with such young children. As a matter of fact, most of the children kept their heads quite still so far as the experimenter could observe.

Group III—Manual Guidance without Vision

Children in Group III were allowed only to grasp the knob with their right hands, and follow it around manually without seeing it. A gray curtain hung before the practice maze, and the arm was thrust through a slit. The maze lights were not turned on, so that the darkened interior was a further prevention of any accidental glimpses. This group, also, was allowed vision on the tests, since it seemed desirable to give all 3 groups the same chance to profit from any learning occurring during the tests. With all other conditions constant, any difference in results should be due to the difference in the training.

The experimental room was to the rear of the house, apart from the main play rooms. The furnishings were familiar to the child, and kept constant throughout the experiment. The noise of the converter and motor, the mechanics of the traveling knob, and the lights were all matters of interest at first. Some of the children soon disregarded them, others continued to manifest some curiosity. The ideal arrangement, of course, would have been to have these isolated. However, the children who continued to examine the set-up when allowed were the more alert, older children who were quickest to learn. Consequently, this interest did not appear to act as a distraction.

The child was brought from his play to the experimental room by the experimenter. On the first day he was first shown the test maze and instructed as follows:

"You see all these paths. Here is a little knob that will go anywhere I move it. Now watch and see what happens when I make it go a certain way."

The experimenter quickly moved the knob through the correct path to the exit, and opened the cookie box. The child was encouraged to look in and take the cookie. He was told that he might have it when he left. He was then shown the practice maze. Children of Groups I and II were told:

"Now I am going to show you on this board the way that little knob must go to make the box open. This little knob will only go the right way, and you may watch it. You must watch it carefully and learn the way it goes, so that you can make that little knob go the same way. I will let you watch it several times, and then you may try it on that board. When you get it right the box will open."

For Group I, the further instructions were:

"Put your fingers on the knob. Don't hold it tight."

For Group II, the addition was: "Put your chin here and your hands here."

Children of Group III, when taken to the practice maze, were told:

"I am going to let you put your fingers on the little knob here and feel the way that little knob must go to make the box open. This little knob will only go the right way, and you may feel it, but the game is not to see it. You must pay attention and learn the way it goes, so that you can make that little knob go the same way. I will let you feel it several times, and then you may try it on that board. When you get it right the box will open."

After each trip of the stylus, the curtain was dropped before the maze, the lights turned off, and the knob drawn back to the starting point. This short interval served as a brief rest period for the child.

After 3 guided runs, the child was led quickly to the test maze and told, "Show me the way it went." The experimenter drew a record of the child's performance in red pencil upon the record sheet. Time was taken with a stopwatch.

After the first period, the instructions were merely "Watch (or feel) carefully the way it goes, so that you can show me and make the cookie box open." Exhortations were confined to: "Watch (or feel) carefully;" "Watch (or feel) where the turns are;" "Try to remember the way it goes," and "You must learn the way the little knob goes if you want to make the cookie box open."

In the beginning each child was taken only twice a week. This proved unsatisfactory both from the point of view of time consumed in the series and for the child's optimum learning. From the first week in December on, each child was taken every day apart from the unavoidable interruptions due to illnesses and holidays.

B. Results: Series 1

From the record sheets, the following data were used as indications of learning: (1) the number of trials to learn; (2) the total distance covered by the child, measured in number of blocks passed, and the average number of blocks passed per test; (3) the total number of turns and the average number of turns per test; (4) the total number of right turns and the average number of right turns per test. The form of the learning curve, and the order of fixation of the turns were observed as of incidental interest. In addition, comments and illustrations of particular features of the learning in individual instances may furnish valuable insight into the process.

Number of Trials. Table 2, column 3, shows these data.

No child under forty-eight months of age learned the maze. Whether Child N would have learned it, had his practice continued, cannot, of course, be stated definitely, but in view of the fact that the three older children in his group did not learn it, it seems extremely doubtful.

Of the four children who learned, the two who were given only visual guidance learned with approximately half as many demonstrations as did those who were allowed to place their hands upon the knob as it traveled. These children were remarkably well matched. The average age and Intelligence Quotient of the two in Group I were identical with those of the two in

TABLE 2

Number of trials and tests, average number of blocks passed, average number of turns and average number of correct turns for each child in Series 1

Less than 99 practice trials indicates that the child successfully completed the learning

CHILD	AGE	NUMBER OF PRACTICE TRIALS	NUMBER OF TESTS	AVERAGE NUMBER OF BLOCKS PER TEST	AVERAGE NUMBER OF TURNS PER TEST	AVERAGE NUMBER OF RIGHT TURNS PER TEST
		Group I. Visual and manual guidance				
	months					
A	57	69	29	16.2	16.5	5.2
B	48	78	29	17.6	20.3	4.5
C	47	102	34	10.5	19.4	1.5
D	40	102	35	18.8	15.0	2.2
E	35	102	34	8.8	17.9	0.6
Average				14.4	17.8	2.8
		Group II. Visual guidance only				
F	57	36	14	16.6	11.9	4.8
G	48	36	15	14.3	8.3	6.1
H	47	102	34	20.4	10.4	1.03
I	46	102	35	13.4	9.5	4.6
J	36	99	33	23.2	14.9	1.05
Average				17.6	11.0	3.5
		Group III. Manual guidance only				
K	52	102	34	16.5	12.6	2.9
L	49	102	34	20.3	14.7	2.9
M	45	99	33	19.4	11.6	2.2
N[1]	43	54	18	15.0	8.0	2.7
O	36	102	33	17.9	11.1	0.9
Average				17.8	12.5	2.3

[1] Due to illness, Child N did not complete the learning series.

Group II. Child A and Child G, the two with the higher Intelligence Quotients, were rather negativistic and bored with the "game"; Child B and Child F were coöperative and interested. Thus, factors other than the difference in training method seem to cancel out. So far as any conclusions can be drawn from the performances of four children, with respect to the number of trials, visual demonstration alone was superior to manual guidance with vision.

None of the children in Group III learned the maze. The two oldest were fully the equal of the successful children in general ability, and were two of the most coöperative and interested children in the experiment. Apparently manual guidance without vision (though with vision allowed on the tests, so that they were not unfamiliar with the appearance of the maze) was an ineffective method of training in this experiment.

Since the ratio of tests to demonstrations was 1:3, except when the child was successful, extra tests indicate isolated successes. Table 2 indicates that Child A made four successful reproductions before he was successful three times in succession. The first of these occurred after 57 demonstrations. Child B also produced one additional true pattern, also after 57 demonstrations. Child G succeeded once after 30 demonstrations. Child D and Child I, although neither reached the criterion of three correct runs, each have one correct pattern to their credit. No child in Group III made even one correct reproduction of the path through which his hand was guided 100 times.

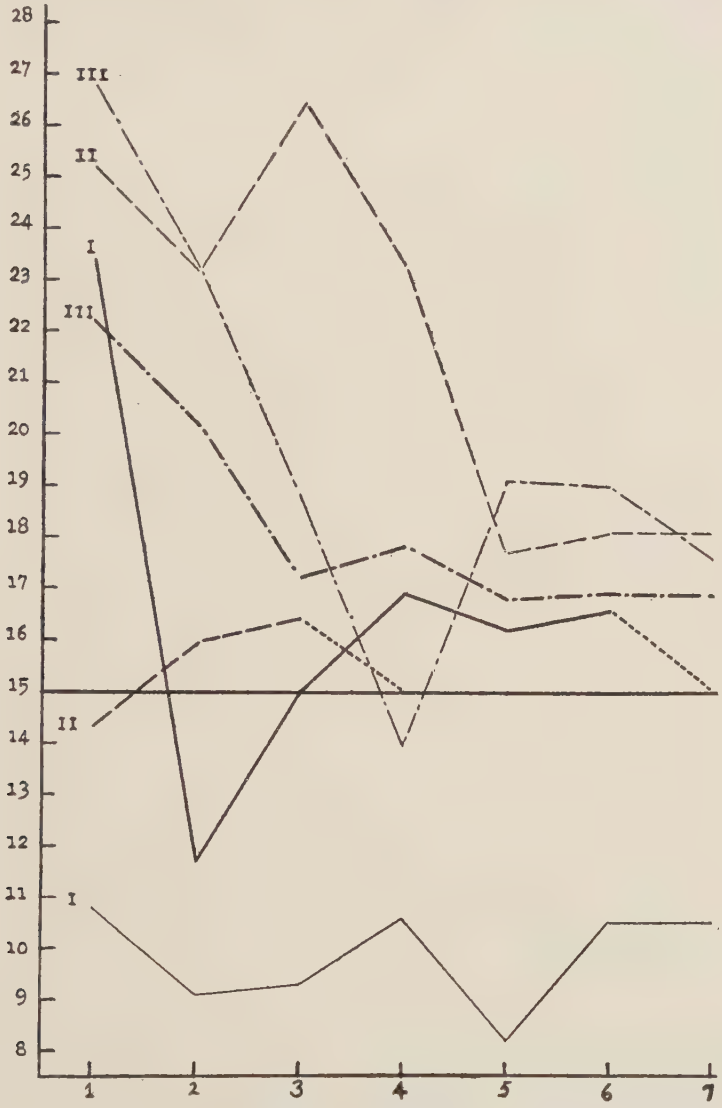
Distance covered. Table 2, column 5, shows the average distance per test covered by each child. Table 3 gives the averages in each successive five tests. The length of the true path was 15 blocks. Group I is nearest to the standard on the average, Group II next, and Group III last.

Inspection of these data reveal small differences between the records of the groups as wholes, or between the performances of those who did and did not learn. The individual differences are much higher than the average differences. Either distance covered is not a criterion of learning in this type of maze, or the number of subjects is not large enough to demonstrate definite trends. Graphic analysis, however, gives an indication of some differences which might or might not be verified in study of a larger group.

Graphs 1 and 2 are drawn from the average number of blocks per each five tests (table 3). Graph 1 shows group averages for the successful and unsuccessful children in Groups I and II compared with the average of their mates in Group III; graph 2 shows individual curves for Child D and Child I who each achieved one successful reproduction, and their mate in Group III, Child N, who did not complete the practice series.

These curves show that the *successful* children in Group I began with much excess distance, which they eliminated, while the *successful* children Group II began below the standard and worked up. With the *unsuccessful* children, the exact reverse is true. The children on the borderline who produced one successful test but not three conform to the tendency for the

successful children of their group (graph 2). The curves for Group III, all unsuccessful, show much excess distance with the exception of Child N (graph 2) whose average deviation in 18 tests is zero. Small average deviations, obviously, accompany good performance, and it is a matter of par-

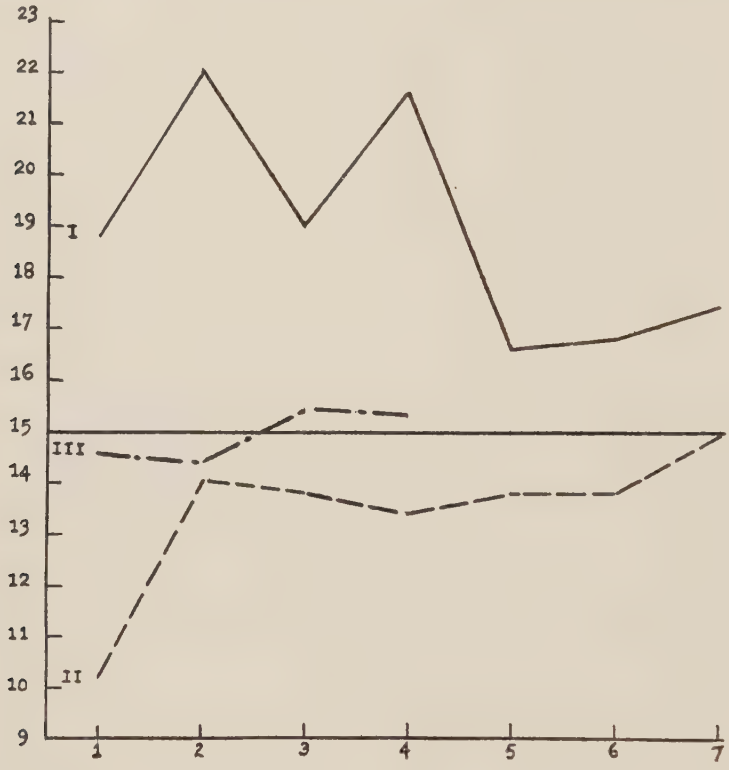


GRAPH 1. NUMBER OF BLOCKS COVERED IN AVERAGE OF EACH FIVE SUCCESSIVE TESTS IN SERIES 1

Curves for successful children in the seeing groups and their mates in Group III (heavy lines) compared with curves for unsuccessful children in the seeing groups and their mates in Group III (light lines). Group I: average A and B ———; average C and E ————; Group II: average F and G — —; average H and J — —; Group III: average K and L —.—; average M and O —.—

ticular regret that his trials could not be continued. It would be possible, on this maze, however, as his performance shows, to approximate the correct distance throughout the tests and yet never achieve the true pattern.

which useless movements are slowly eliminated. Yet with manual guidance alone, complete learning in this problem did not occur. The addition of vision was necessary to bring success. Moreover the short curve of



GRAPH 2. NUMBER OF BLOCKS COVERED IN AVERAGE OF EACH FIVE SUCCESSIVE TESTS IN SERIES 1

Children successful on one test, but not on three in succession, and their mate in Group III. Group I: Child D ——; Group II: Child I — —; Group III: Child N —.—

These differences in the direction of the deviation may be due only to individual variations in so small a group. On the other hand, they may reflect the effect of manual guidance. Where manual guidance was given exclusively or in part, such learning as occurred was characteristic of the motor type in Group II is very much like the second half of the curve of Group I. This suggests the possibility, at least, that the children who had visual demonstration only (Group II) did their preliminary exploration visually, and that those who failed to do so in this group, failed to learn the maze.

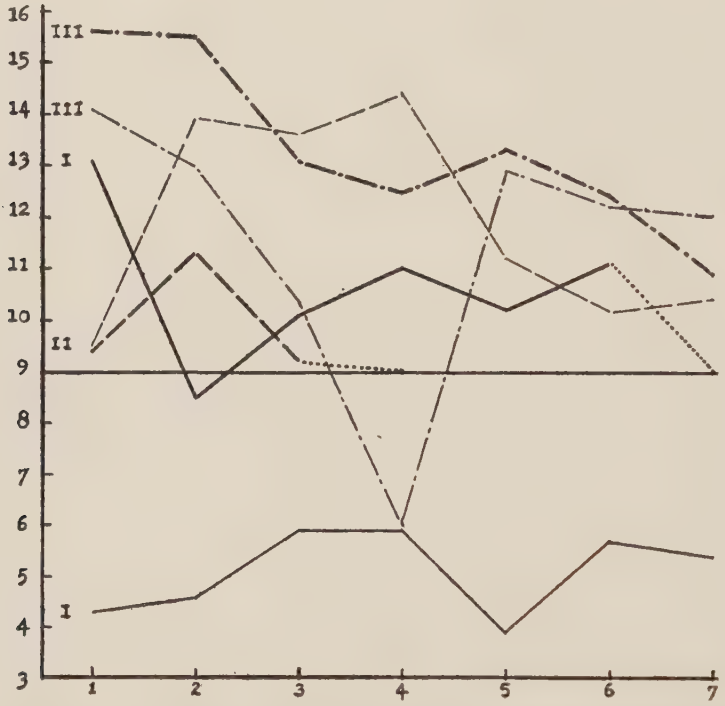
TABLE 3

Distance and turns for each child as shown by the average for each five successive tests

			Group I				
			Average number of blocks per five tests				
A	20.8	11.8	14.4	18.4	15.4	17.0	
B	26.4	11.6	15.6	15.4	17.0	16.2	
C	13.4	6.8	7.8	10.6	10.2	12.8	15.5
D	18.8	22.0	19.0	21.6	16.6	16.8	17.4
E	8.2	11.4	10.8	10.6	6.2	8.2	5.5
Average...	17.5	12.7	13.5	15.3	13.1	14.2	12.8
			Average number of turns per five tests				
A	12.2	5.8	10.2	12.8	8.8	12.5	
B	14.0	11.2	10.0	9.2	11.6	9.6	
C	4.2	2.2	2.4	6.4	6.2	8.8	10.0
D	11.8	17.2	12.2	15.6	15.6	13.2	14.4
E	4.4	7.0	9.4	5.4	1.6	2.6	0.8
Average...	9.4	8.7	8.8	9.9	8.8	9.3	8.4
			Group II				
			Average number of blocks per five tests				
F	14.8	17.2	18.2				
G	13.8	14.6	14.6				
H	27.8	24.4	22.8	20.6	12.8	16.4	17.3
I	10.2	14.0	13.8	13.4	13.8	13.8	15.0
J	22.6	22.0	30.0	26.0	22.6	19.8	18.9
Average...	17.8	18.4	19.9	20.0	16.4	16.7	17.0
			Average number of turns per five tests				
F	9.8	13.6	10.0				
G	9.0	9.0	8.4				
H	10.0	14.8	12.0	12.4	5.8	7.4	8.4
I	7.8	9.8	10.2	9.2	9.6	9.8	9.8
J	9.0	13.0	15.2	16.4	16.6	13.0	12.3
Average...	9.1	12.0	13.2	12.7	10.7	10.1	10.2
			Group III				
			Average number of blocks per five tests				
K	12.2	15.0	16.4	20.2	19.2	18.6	13.2
L	33.2	25.4	18.0	15.4	14.4	15.2	20.5
M	15.0	27.4	25.0	15.0	20.0	22.0	17.0
N	14.6	14.4	15.4	15.3			
O	28.6	19.2	12.6	13.0	18.2	16.0	18.3
Average...	20.7	20.3	17.5	15.8	17.9	17.9	17.3
			Average number of turns per five tests				
K	10.4	10.4	11.6	14.2	17.0	13.8	10.0
L	20.8	20.6	14.6	11.8	9.6	11.0	11.8
M	10.0	12.6	12.4	7.2	11.2	16.4	11.0
N	8.6	8.4	8.0	6.3			
O	18.2	13.4	8.4	5.8	14.6	9.0	13.0
Average...	11.8	13.0	14.4	11.2	13.6	13.6	10.1

Number of turns. Table 2, column 6, gives the data for the number of turns. The correct number of turns was 9. The average for Group I is closest to the standard, that for II next and III last. This is the same order that was shown for distance, though the differences were not quite so large. In either case, the number of subjects and the size of the difference is not large enough for statistical reliability. But if the direction of the differences is taken at face value, then it appears that the combination of visual and manual guidance in Group I was most effective in producing the correct amount of distance covered and the correct number of turns, *on the average.* None-the-less, the correct reproduction of the pattern occurred much sooner by the second method.

The curves drawn from the averages of turns for 5 successive tests in table 3 show the same general characteristics as those for distance. Comparison of the two sets helps to summarize the observations possible from these measures of the learning. In the following, 15 blocks and 9 turns are taken as the "standards" in distance



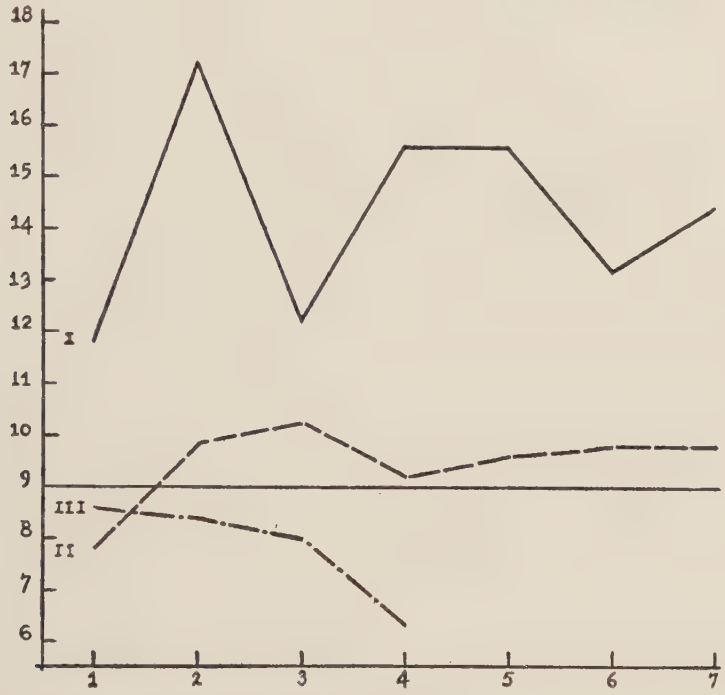
GRAPH 3. NUMBER OF TURNS IN AVERAGE OF EACH FIVE SUCCESSIVE TESTS IN SERIES 1

Curves for successful children in the seeing groups and their mates in Group III (heavy lines) compared with curves for unsuccessful children in the seeing groups and their mates in Group III (light lines). Group I: average A and B ———; average C and E ————; Group II: average F and G — —; average H and J — —; Group III: average K and L —.—; average M and O —.—

and turns, and deviations above or below these are called simply plus or minus variations.

In Group I the *successful* children vary in distances from 8.4 to −3.3 blocks, or through 11.7 blocks; the *unsuccessful* from −4.2 to −6.8 blocks, or through only 2.6 blocks. In turns, as in distance. *Failure* apparently resulted from lack of initial excess activity, or random exploration.

In Group II the *successful* children varied from −.7 to +1.4 blocks, or through 2.1 blocks; the *unsuccessful* from +11.4 to +2.7, or through 8.7 blocks. In turns the *successful* chil-



GRAPH 4. NUMBER OF TURNS COVERED IN AVERAGE OF EACH FIVE SUCCESSIVE TESTS IN SERIES 1

Children successful on one test, but not on three in succession, and their mate in Group III. Group I: Child D ——; Group II: Child I — —; Group III: Child N —.—

the *successful* children varied from +4.1 to −.5 turns, or through 4.6 turns, while the *unsuccessful* varied from −3.1 to −5.1, or through 2.0 turns. Requirements for success by this method of guidance, then, appear to be: (1) a considerable amount of excess distance to be eliminated; (2) some excess in turns, but not so much

dren varied from +2.3 turns to 0; the *unsuccessful* from +5.4 to +.5, or through 4.9 turns. *Success from this method of guidance*, then, appears to require almost no excess activity in distance and a similar close adherence to the standard in turns, with about the same amount of variation in each. *Failure* in this case resulted from *ex-*

cess activity both in distance and in turns.

In Group III, manual guidance only, the deviation from the standard is strongly positive in all cases except for the one point below the standard in graph 3.

It is tempting to speculate here. The manual guidance without vision resulted in excess motor activity, rather undirected, in which a slow approach to the correct distance and number of turns occurred, but the pattern was not learned. As a previous author observed, kinesthesis may indicate that a turn is to be made, but visual or tactual cues are needed to indicate where. Members of Group I perhaps reacted to the manual guidance first, and their records show the motor pattern in the beginning. Later, when unsuccessful, they changed to a visually guided reaction. Those who were allowed only to watch the knob possibly gave their whole attention from the beginning to the visual guidance of their hands in the test situation.

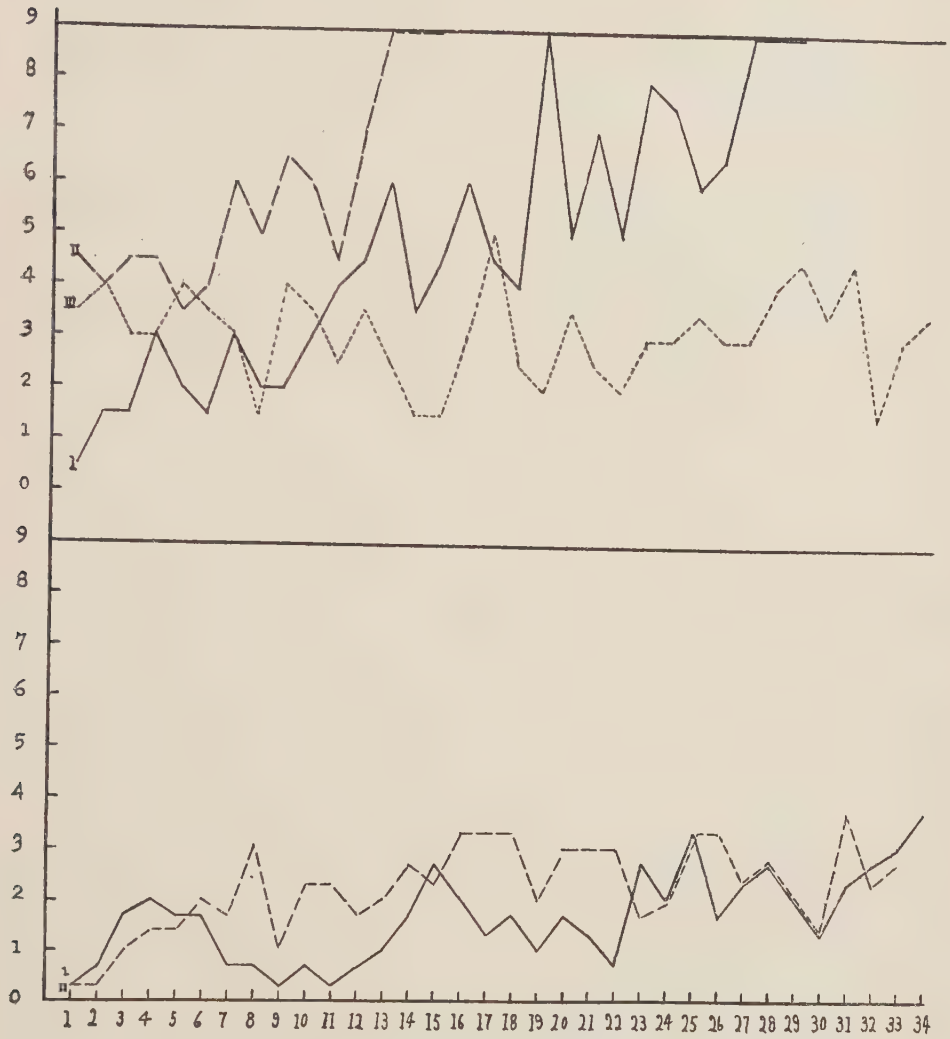
Whether verbalization entered into the learning or not was not ascertained in this study.

The individual curves, (graphs 2 and 4) illustrate partial learning in Child D and Child I, and incompleted series for Child N. Child D did not improve on the average in number of turns, but did improve in distance. Child N, though he judged the distance very well, was slowly departing from the standard in number of turns.

Number of right turns. The type of maze used offered scoring difficulties. Whereas in the ordinary maze, each excursion into a cul-de-sac must be followed by a return to the correct path at the same point where it was left if the exit is to be reached, in this maze the subject might leave the true path at any point and join it again later, or not at all, after any amount of random exploration. Where the record contained more or less than the requisite 9 turns, even though a few of the turns were at the correct point, it was not possible to be sure which part of the pattern the child had intended that particular section to represent. The method finally adopted to overcome the difficulty was simple. Turns were counted as correct if they occurred at the correct point in consecutive order counting *either* from the *beginning* or the *end* of the pattern. Thus, if a line in the right direction traveled around turn 6, it was counted as correct if, in the child's pattern, it was the sixth turn from the beginning or the fourth turn from the end. According to this scheme, table 2, column 7 shows the results.

This record gives a more accurate reflection of the child's performance than does the distance or the total number of turns. Here the group averages are in agreement with the fact that children of Group II learned in fewer trials than those of Group I. Child N, whose total distance and turn scores were so much nearer the standard than those of others of his group, none-the-less had no more right turns than the majority of the others. Child I, it is true, has as high a score as some who were successful, but his record shows that he repeated a pattern a great many times in which a number of the turns were correct without correcting the few mistakes.

The most striking fact throughout this analysis is that no differences can be shown which are in any way large enough to account for the fact that Children F and G learned the pattern in half as many trials as Children A and B. The averages of distance covered, of turns per test, and of right turns per test are different from those of the children who did not learn the maze, but not strikingly different from each other. Only in the graphic repre-



GRAPH 5. LEARNING CURVES CONSTRUCTED FROM THE NUMBER OF CORRECT TURNS PER TEST

A. Group averages for successful children in the seeing groups and their mates in Group III. B. Group averages for unsuccessful children in the seeing groups.

sentation of the *direction of deviation*, do we find a clue which might point to a solution of the problem, namely: that the 2 children who learned with the aid of motor guidance tended toward excess motor activity in the beginning, while those who only watched the knob avoided this preliminary stage.

The form of the learning curve. Graph 5 shows the learning curves, constructed from averages of the number of right turns per test of Children A and B, F and G, K and L, C, D and E, and H, I and J. Group differences are marked. The successful children in Group II started at a higher level than those of Group I. On the first trial they attained a score not reached by the two children of Group I until the twelfth test. Again, the saving by this method is shown to have been in the first half of the learning curve.

The curve for the average of Children E and L in Group III ends at exactly the same point as it began. It even has a slight downward slope for the first half of its course, although it began nearly as high as the curve for Group II. In fact it appears to represent admirably the efforts of a person groping in the dark. The curve for the remaining three children in Group III has not been included since it is similar to this although upon a lower level.

The curves for the unsuccessful children in Groups I and II are consistent with those shown by the successful children and display the same differences at a lower level. Although in this case they begin at the same point, the curve for Group II never sinks to the starting level again after the second test, while Group I falls to the starting point again on the ninth and eleventh tests. The rise of the curve in its first half is steeper in II than I and the high level is maintained more consistently in the former.

TABLE 4

Relative difficulty of turns in the maze

	TURN NUMBER								
	1	2	3	4	5	6	7	8	9
Times correct	352	125	39	36	35	104	135	146	215
Rank in difficulty	(1)	(5)	(7)	(8)	(9)	(6)	(4)	(3)	(2)

Order of fixation of turns. From the total number of times each turn was correctly negotiated, the order of difficulty of the turns in the maze was calculated. This is shown in table 4.

This is consistent with other studies which have shown the first and last items of a series to be the first learned, while the middle items are the hardest. In this case the third, fourth and fifth turns proved about nine times as hard as the first turn and about six times as hard as the last.

Comments upon individual performances. There were several varieties of failure, which no mathematical treatment of the records can bring out. They reflect both the results of the

method of guidance and the personal reaction of the child. Some of these are the following:

1. Aimless wandering. Child M's record was typical. He started out well, but apparently was lost after the third turn and retraced up and down the grooves until stopped at the end of 45 seconds by the experimenter.

2. Quick, impulsive action with (a) no apparent attempt to reproduce the pattern, or (b) a very much abbreviated pattern.

3. An attempt to produce a pattern, but with no similarity to the true pattern.

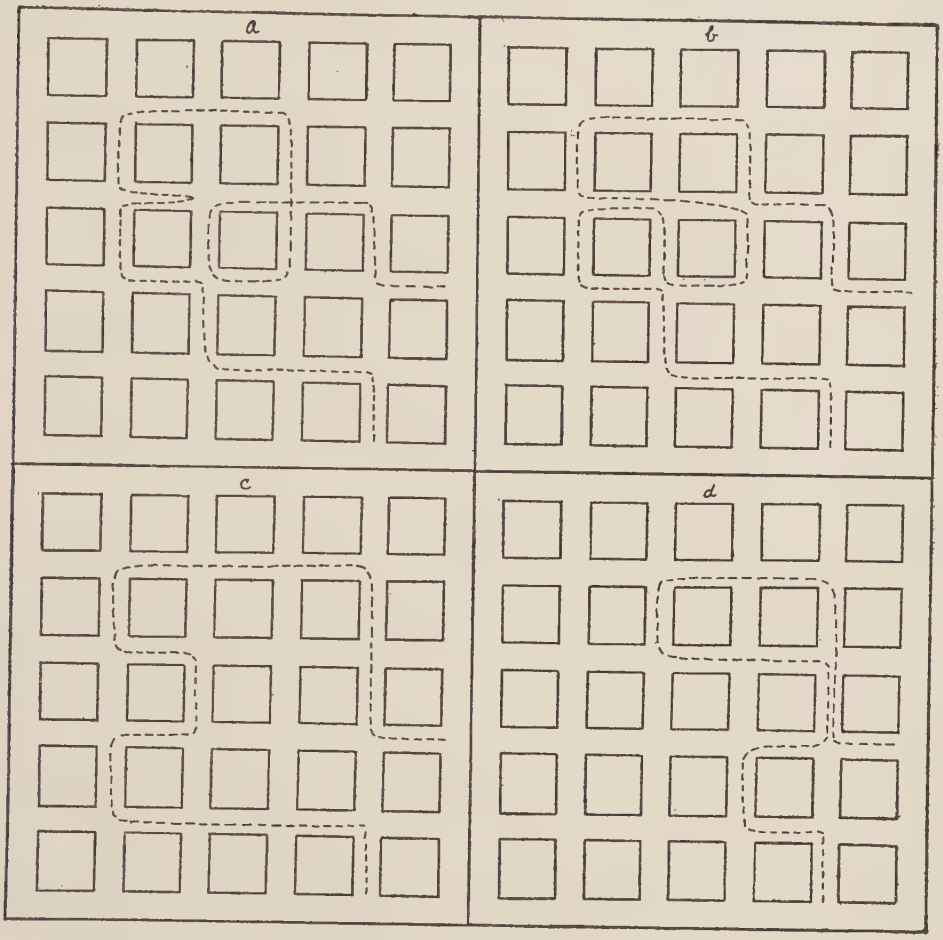


FIG. 4. INDIVIDUAL RECORDS

a. Child K, age 52 months. Test 1 after 81 guided trials, time 19 seconds. *b*. Child K age 52 months. Test 1, after 87 guided trials. Time not taken. *c*. Child L, age 49 months. Test 1 after 75 guided trials, time 18 seconds. *d*. Child L, Test 1 after 96 guided trials, time 9 seconds.

4. The best records of the oldest children in Group III are extremely interesting. They show varying approximations to the pattern in the

effort to reproduce a series of unseen hand and arm movements. Child K (see figure 4) evidently felt he should go around the middle block, but could not find the way to start. Child L has the number of turns correct in both records, also the direction of the turns and some of the proportions. Such records as these often occurred just before learning among the older children in Groups I and II. Child L never eliminated these errors.

TABLE 5

Age and intelligence quotients of children for the second series of demonstrations

1. *Reduced maze,* trials and tests as in Series 1

CHILD	AGE	I.Q.	CHILD	AGE	I.Q.
Group I. Visual and manual guidance			Group II. Visual guidance only		
	months			*months*	
C	51	100	H	51	115
D	44	112	I	50	110
E	39	102	J	40	110
Group III. Manual guidance only			Group IV. No vision on tests or trials		
K	56	118	R	52	96
L	53	113	S	50	123
M	49	126	T	43	111
O	40	133			

2. *Original maze,* no vision on tests or trials

Group Va. No previous trials			Group Vb. Previous success with vision		
P	58	98	F	61	108
Q	49	117	U	54	140
			B	52	107
			G	52	123

IV. SERIES 2

A. Subjects and procedure

At the completion of the first series of 100 demonstrations for each child, the following questions arose:

1. Since the problem, as it stood, was too hard for the younger children of the two seeing groups, would it be possible for them to learn it if it were simplified by shortening the maze?

2. Could any of the children of the non-visual group learn the path if it were simplified by shortening?

3. Was the introduction of vision on the tests for the non-visual group really a confusing rather than facilitating procedure?

4. Could children who had once learned the maze with vision relearn it without vision?

To settle these questions, a new series of 100 demonstrations each was given to six groups, under the conditions indicated in table 5. The age

is given as of March 1, 1934, when this series was begun.

The original maze was shortened, as shown in figure 5, by covering the outer row of blocks on two sides of the maze with an L-shaped sheet tin lid, painted the same color as the maze. Four turns, the first two and the last two, were thus cut off from the original pattern, making the length of the true path 9 blocks, and the number of turns, 5. Since in the original, the end of

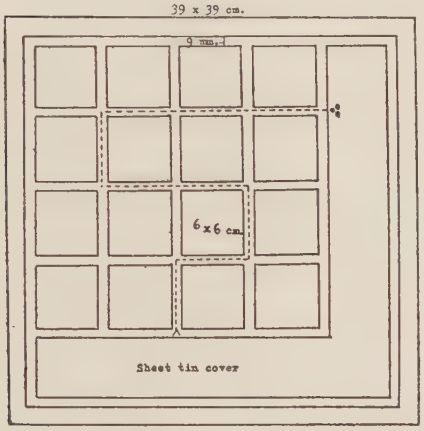


FIG. 5. SURFACE VIEW OF REDUCED MAZE
The dotted line indicates the path traveled by the knob on the practice maze.

the path was clearly marked by the exit from the maze, the finish in this reduced pattern was marked by the three small gold stickers shown in this diagram.

Groups IV and Va were instructed just as Group III had been previously, but when they were taken to the test board the curtain was not removed.

Group Vb was told:

"You remember how we played this game the last time. You learned the way the little knob went, and you made the cookie box open. The little knob still goes the same way it did before. I want to see if you can make the cookie box open when you cannot see the way the knob goes."

Groups I, II, and III were told: "You see, I have covered up some of the blocks in the game. The little knob does not make so many turns, and it may be easier for you to remember the way it goes.

"We will play this game just the way we did before. When you make the little knob go the right way the box will open. I will show you the right way over here, and you will show me there."

The rest of the procedure was precisely the same as in the previous series.

B. Results: Series 2

Number of trials. The results of this series are presented according to the same scheme as that for the previous series. Table 6 shows the number of trials for each child.

Table 6 answers the questions stated. No child who was not permitted vision on the tests or trials (Groups IV, Va, and Vb) learned the maze, not even children in Group Vb, who had previously learned it with vision. Not one of these children, in fact, produced even one correct pattern.

Three of the younger children, who had not learned the full maze in the seeing groups, learned the reduced maze. Child D, and Child I, both of whom produced one correct test on the full maze but were unable to reach the criterion of 3 perfect tests, learned this easier pattern after very few demonstrations. Child I, having visual guidance only, learned after 6 trials, just

half as many as were needed by Child D, who received visual and manual guidance. This is exactly the same ratio as obtained between the number of trials required for successful learning by the older children trained by these methods in Series 1.

efficacious at about three years and under. However, a special circumstance should be related in this case. This child never appeared to comprehend the instructions very clearly. After the thirteenth test, when the experimenter had brought him back to

TABLE 6

Number of trials and tests for each child

Less than 99 trials indicates that the child successfully completed the learning

Reduced maze

CHILD	AGE	TRIALS	TESTS	CHILD	AGE	TRIALS	TESTS
Group I. Visual and manual guidance				Group II. Visual guidance only			
	months				*months*		
C	51	102	34	H	51	102	34
D	44	12	7	I	50	6	4
E	39	78	28	J	40	99	33
Group III. Manual guidance only				Group IV. No vision on tests or trials			
K	56	15	7	R	52	102	34
L	53	102	34	S	50	102	34
M	49	102	34	T	43	102	34
O	40	102	34				
Original maze. No vision on tests or trials							
Group Va. No previous trials				Group Vb. Previous success with vision			
P	58	99	33	F	61	99	33
Q	49	102	34	U	54	99	33
				B	52	99	33
				G	52	102	34

Child E (Group I) learned the maze in 78 trials, while Child J (his partner in Group II) did not complete the learning. This is the only instance in which the combined manual and visual guidance appeared superior to the visual only. This might be due to individual variations. On the other hand, we may have here an indication that manual guidance actually is more

the practice board for the fortieth trial, she said, "I believe you really know the way that little knob goes. It starts here, and where does it go next?" To her amazement, he indicated the correct path with his finger, and could do it as many times as asked. He was then taken back to the test board and told: "Now do just what you did over there. It starts here, and where does

it go next?" He was unable to produce the correct pattern on the test board, although he approximated it. Thereafter the trials and tests continued as before, the experimenter saying for each test: "Where does it go next?" The child did not succeed in the usual manner on the test board until after twice as many trials as this demonstration on the practice board required, and it is probable that he could have shown the way earlier on the practice board if he had been asked. Possibly he had observed small cues there which pointed out the path to him without his actually having learned it. No other child was found who exhibited this ability on the practice board, or to whom the change in the wording of instructions seemed to make any difference, although others of the younger group were tried after this discovery.

Child K (Group III), learned the pattern to the point of three correct reproductions after fifteen trials on the reduced maze with manual guidance only. Child K was the oldest child in Group III. Kinesthesis, far from being the best guide at the youngest ages, was only beginning to be an adequate guide for a child almost five years old, and this when vision was allowed in the test situation.

Distance covered. The total distance covered by each child and his average distance per test and per five tests were calculated for this series as in the previous series. The complete table has been omitted as unnecessarily cumbersome. The length of the true path for the reduced maze was nine blocks.

The same trends observed in the first series were even more evident here. Group averages of the number of blocks covered per test compared with the standard show the following deviations: On the reduced maze, Group IV +14.2 blocks, Group III +1.3 blocks, Group II +.6 blocks, Group I −1.4 blocks; on the full maze, Group Va +12.2 blocks, Group Vb +1.2 blocks. The ranking of the groups by average deviation (in which the positive and negative deviations are disregarded) is the same as that above except that Groups I and II change places, Group I having a higher average deviation than Group II.

These results emphasize once more that vision tends to reduce random motor exploration. The introduction of vision in the test situation in Group III of Series 1 was an aid, not a confusing factor. Groups IV and Va, composed of children who had not previously been trained on the maze and who were allowed vision on neither the practice nor the tests, show the largest amount of excess distance covered. Next in order is Group III, children who had never had visual guidance. Group IVb ranks next, although there is only 0.1 block difference between this and Group III. These children had previously learned the maze with vision, but were allowed no vision either on practice or on tests in this series. The effects of the previous visual training about equalled the effects of vision on the tests.

It might be expected that Group I should rank next in order as showing the effects of the manual guidance, and Group II last. In Series 1, as we noted there, the same reversal occurred, due to the wider negative deviation of

GRAPH 6. REDUCED MAZE. NUMBER OF BLOCKS COVERED IN AVERAGE OF EACH FIVE SUCCESSIVE TESTS IN SERIES 2

Curves for successful children (heavy lines) compared with curves for unsuccessful children (light lines). Group II. I is not an average of five tests, but the actual tests, as there was only one previous to success. Group I: D and E ———; C ————; Group II: I — —; average H and J — —; Group III: K —.—; average L, M, O —.—; Group IV: average R, S, T .....

GRAPH 7. ORIGINAL MAZE. NUMBER OF BLOCKS COVERED IN AVERAGE OF EACH FIVE SUCCESSIVE TESTS IN SERIES 2

Group Va: average P, Q ——; Group Vb: average F, U, B, G — —

the unsuccessful children overbalancing the positive deviation of the successful in Group I. Here the same explanation would hold were it not for the case of Child E, already described as unusual. The effect of one record in so small a number of cases unfortunately calls all the group results into question.

Graphs 6 and 7 drawn from the averages of successive five tests illustrate the above observations and are in most respects consistent with the findings from the previous series. With the exception of Child E, the younger children who were successful on the reduced maze were those who had been on the verge of learning the larger maze and a very few trials on this easier problem sufficed to bring them to the criterion of three perfect tests. Child E is an exception to the previous progress of successful children in Group I. Child K, the only child in any series successful by the manual guidance alone, is surprising in that his short curve is like that of Group II instead of Group I.

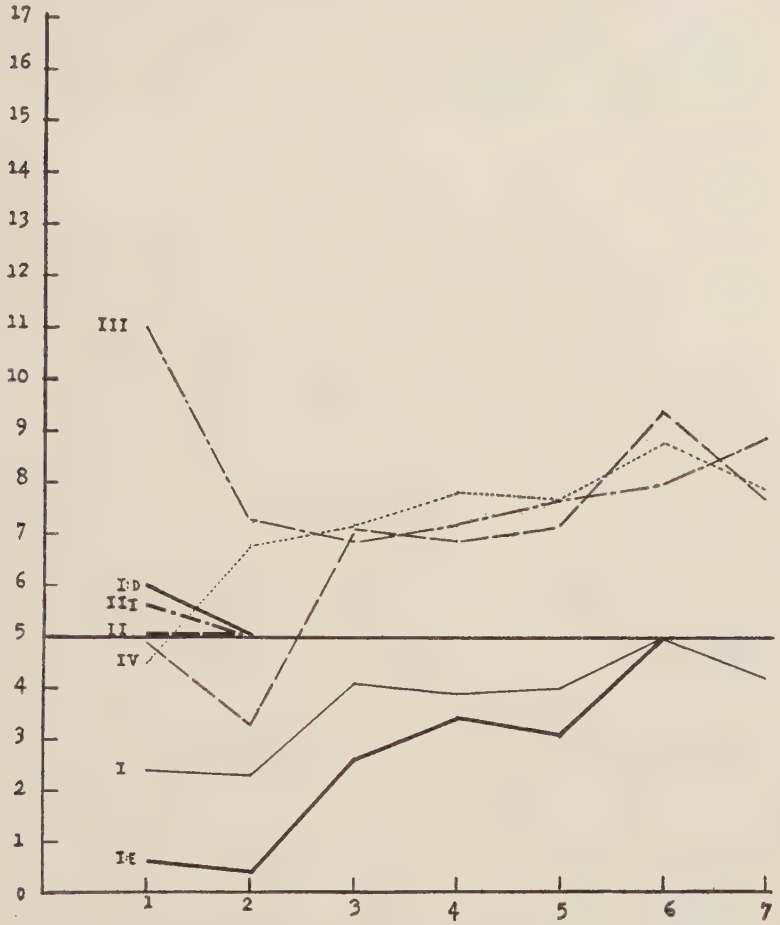
Number of turns. The number of turns for each child was also counted and treated as in Series 1. It was noted that while the amount of deviation from the standard for Groups I, II, III and IVa was very nearly the same for distance and for turns, with Groups IV and Va the deviation from the standard in distance was about 7 and 2 times, respectively, the deviation from the standard in number of turns. The absence of visual guidance on both trials and tests encouraged random retracing and a maximum of distance covered with a minimum of turns.

The form of the learning curve. The number of correct turns for each child was determined by the method described in Series 1. The group averages for the number of right turns per test is as follows: Group I, 1.8; Group II, 2.1; Group III, 1.5; Group IV, 0.2; Group Va, 0.7; Group Vb, 2.5. (See graphs 8 and 9.) The surprising feature here is that Group Vb has the highest average, although not one child produced an entirely correct test. The effects of the previous success with vision were strong enough to bring these children to the first rank by this criteria, whereas children learning by the same method who had had no previous practice series (Groups IV and Va) ranked last. Children who had had as much previous practice in Series I without vision on the practice but with vision on the tests ranked fourth in order. As in the previous series, Group II was the best of the three original groups.

The unsuccessful children in Groups I, II and III differ from those of the previous series in that Groups I and II show no upward trend, Group III does after trial 26. It is probable that the children who did not learn with vision at this level never comprehended the problem, and that the slight upward trend of the curves of unsuccessful children in Series 1 was due to the presence in the group of the children who were successful on the reduced maze of Series 2. In Group III the older children began to succeed a little better with the easier problem.

In summary, the results of Series 2 show that the reduction in size of the maze made the problem of about the

same difficulty for the younger children that the original maze was for the older ones. Learning without visual guidance was more difficult for the older children of Group III on the short maze than the original maze had been for the younger children of the seeing groups. Learning without vision on the tests or practice was by far the most difficult method of all. In most respects the indications from Series 1 were confirmed by Series 2, where the same phenomena appeared upon a lower level. The less visual and the more manual the training and testing, the more random motor ac-

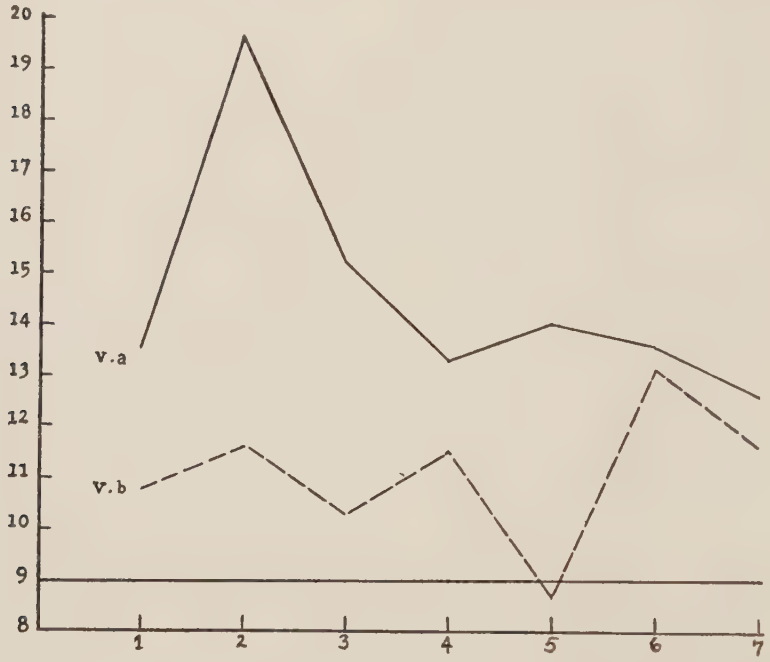


GRAPH 8. REDUCED MAZE. NUMBER OF TURNS IN AVERAGE OF EACH FIVE SUCCESSIVE TESTS IN SERIES 2

Curves of successful children (heavy lines) compared with curves of unsuccessful children (light lines). Group II, I, is not an average of five tests but the actual tests, as there was only one previous to success. Group I: D and E ———; C ————; Group II: I — —; average H and J — —; Group III: K —.—; average L, M, O —.—; Group IV: average R, S, T .....

tivity occurred, and the less was the likelihood of success. Such a decided contrast probably would not be found with a different type of maze in which random activity itself would be likely to produce eventual success.

Comments upon individual performance. Some varieties of failure beings, and particularly in connection with Rice's recent study of this feature, the record of Child J (figure 7) is interesting as an example of a pattern which recurred many times, among the unsuccessful children. This reversal of the pattern in turning left instead of right at the first turn also



GRAPH 9. ORIGINAL MAZE. NUMBER OF TURNS IN AVERAGE OF EACH FIVE SUCCESSIVE TESTS IN SERIES 2

Group Va: average P, Q ——; Group Vb: average F, U, B, G — —

came more obvious in this second series than they had been in the first. Aimless wandering was carried to the extreme in the non-visual groups, with emphasis upon retracing. Child P's record on the long maze, shown in figure 6, is an example of this tendency.

In connection with observations by the early child psychologists upon the lack of orientation in children's drawoccurred in the long maze at this point, where it was the third turn instead of the first. Once this had appeared, it seemed especially difficult to eradicate. Thirteen of Child J's tests, 14 of Child L's, 15 of Child M's and 8 of Child O's records were of this pattern. All the children of Group III, in fact, seemed unable to correct this error. The kinesthetic impulses evidently in-

dicated a turn, but not the direction of the turn. Child M, after 90 trials and his thirtieth test, remarked "Well, that's wrong, but that's the way it went, though."

Child O was the only one who seemed confused by the change from the large to the smaller maze. His record, shown in figure 7, is peculiar in that he actually reproduced the pattern in his first five turns several times, but he never learned to stop after this performance. Instead he continued as shown in his record. He appeared to be trying to get to the exit from the long maze, where the cookie box was.

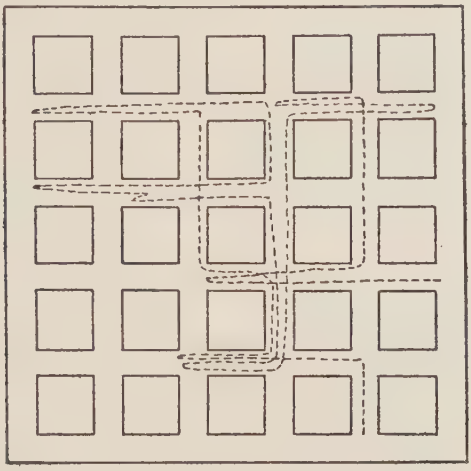


FIG. 6. INDIVIDUAL RECORD OF CHILD P, 58 MONTHS OLD
Test 1 after 18 guided trials, time 39 seconds

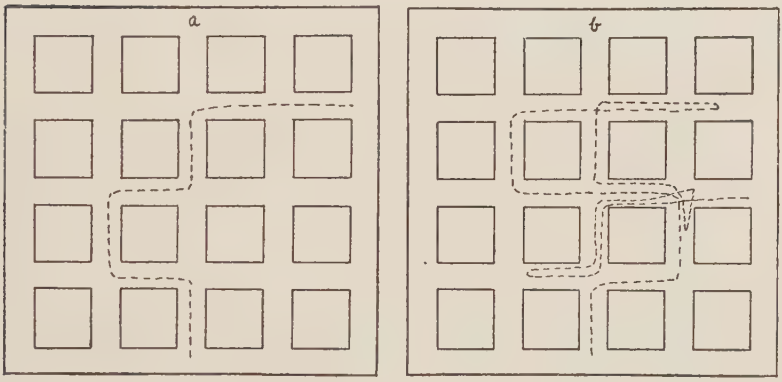


FIG. 7. INDIVIDUAL RECORDS
a. Child J, 40 months old. Test 1 after 87 guided trials, time 7 seconds. *b*. Child O, 40 months old. Test 1 after 81 guided trials, time 20 seconds.

CONCLUSIONS

The goal of this study was to set up a problem in which children must learn a motor task by one of three methods: (1) through predominantly visual cues, (2) through predominantly manual cues, or (3) through a combination of the two. If there is a tendency for children to depend primarily upon kinesthetic cues other than visual, it was hoped this experiment would demonstrate that fact.

There were 21 children in the experimental group. This small number of cases prevents the statement of definite conclusions. Nevertheless, the results appear to present very definite indications in some directions, while other more tentative findings open interesting avenues for speculation.

There is little doubt that the method of training in which manual guidance without vision was employed was much less effective in producing successful learning than were the visual methods. Preliminary trials with 6 adults had shown that manual guidance without vision presented a real problem to them in reproduction, but the assumption that the adult has shifted to visual dominance while the young child relies mainly upon tactual-kinesthetic cues, would lead us to expect the opposite results with children. This was not the case.

The facts upon which the relative difficulty of the non-visual method is asserted are the following: (a) No child in the non-visual group (no vision in the guided practice trials, vision on the tests) learned the correct pattern in the long maze, whereas four older children in the visual groups (vision on both practice trials and tests) did learn it. (b) When the maze pattern was shortened, only the oldest child in the non-visual group learned the pattern, while 3 of the younger children in the visual groups learned this easier task. (c) Vision on the tests only was of considerable benefit, as shown when the non-visual group of Series 1 was compared, in Series 2, with a group allowed no vision either in practice or in tests. By the criteria of distance covered, number of turns, and number of correct turns, the first group came much nearer to the standard than the second. It is probable that the vision in the tests was in some ways comparable to the insertion of visual trials. (d) Children who had once learned the maze with the aid of vision were unable to relearn it without vision on practice or tests, although the effects of their previous visual training were obvious when distance and turns were compared with the other non-visual groups.

Differences between the two visual groups (visual guidance only, and visual and manual combined) are not so definite, but tend to show that visual guidance alone is superior to the combination. This conclusion rests mainly upon the comparative number of trials required by the successful children in both groups. Success by the visual guidance was attained in half as many trials as by the combination. Since this relationship rests upon the records of only 6 children, the individual variation may have biased the results. The youngest child in the visual-manual group was successful on the easier problem, while the youngest child in the visual group was not.

The manual guidance alone resulted in wide random exploration on the tests. This was still more marked when vision was not allowed on the tests. Visual guidance alone resulted in quite limited initial exploration among the successful learners. Possibly here the preliminary exploration had been visual. Visual guidance on the trials probably requires less passivity on the part of the child than the manual, since the eyes may explore the maze and return to the moving knob during guidance, while this is not possible in manual "putting through." This does not explain, however, why the combined method was less effective than the visual alone. Possibly, the combined method involved a division of the attention between the two types of cues, and the manual cues acted as a stimulus to excessive activity and therefore as a distraction from the problem itself, rather than as an aid.

It is possible that visual guidance was at a premium in the set-up of this problem as was the case in some experiments of Richardson's (30) and in Walton's (34) study with rats. In that case, the conclusion is simply that children, as young as three years, can learn a motor task of a certain degree of difficulty when it is presented to them visually.

Carr (4 and 5), on the basis of his study where visual and manual guidance were combined, suggested the alternatives that the effect of vision might be (1) a visual memory of the maze; (2) prevention of tactual-kinesthetic errors in the learning process. This study, in which visual guidance without manual proved more effective than a combination, throws weight toward the visual memory hypothesis.

Carr (4) was also of the opinion that individuals develop a visual idea of a maze pattern through non-visual guidance—an opinion opposed by the work of Brown, Husband, and Cutsforth. Our results indicate that if any visual idea was developed by these children through the manual guidance alone, it was an entirely erroneous one.

Other studies of method (35) showed that of the three methods of learning, verbal, visual imagery, and kinesthesis, the verbal was most effective, visual next, and the kinesthetic least. It was generally assumed that the learning of young children was mainly kinesthetic. Results of this study indicate that by three-and-a-half to four years at least, vision plays an extremely important rôle. It seems likely that any shift in receptor dominance from the kinesthetic to the visual modes has occurred by this age, and not as late as puberty—as some have advocated. The later shift is more likely toward increased dependence upon verbalization in ideational activity.

Whether verbalization played a part in the learning could not be ascertained. Some of the children could count as high as 10, but their actual concepts of number were not above four or five objects. Even granting their ability to count the turns, it is doubtful if this method occurred to them. Pyles' (25) study showed that naming of objects was an aid to learning but there the learning consisted in identifying an object of geometrical design, not repeating a movement. Johnson (17) found that children four

to five years of age remembered two to three movements in the Knox Cube test after one demonstration. Repeated demonstration, in this study, resulted in memory of the successive movements in a longer series.

These results show that the lack of improvement in the ability of young children to reproduce a pattern, found by Hicks and Ralph (12) in a study of practice in tracing the Porteus Maze, and by Rice (29) after eye and hand training on the diamond, was probably due to the small amount of practice given in these studies. In this study, children three years of age improved measurably in ability to reproduce a complicated figure after 100 visually guided trials, even where learning was not complete. Rice's finding that success in reproduction was correlated with perceptual level rather than motor ability is confirmed and further defined by this study. Her work implies that perceptual level is dependent upon age and cannot be improved by training. This study indicates that it can be improved if the training is continued long enough.

With reference to the problem as stated in the beginning (p. 315) it has been demonstrated that stimuli initiated by the visual processes alone can produce appropriate motor responses in children as young as three years. Whether children younger than this must rely on kinesthetic stimuli from the responding organ itself for skillful motor activity is yet to be shown.

Further research on this problem should be directed, first, toward verifying the findings here presented with a larger group of children.

The disadvantage of this particular apparatus is in the difficulty in recording errors. A set-up which permits automatic recording of the child's performance should be devised.

This experiment has shown that visual cues were indispensable for learning in this particular situation. Other studies have indicated that it is less necessary in other situations. Analysis of the factors which are responsible for this difference should be attempted. There are indications in this study that cues from the manual guidance may result in elimination of excess distance after long training, and the correct number of turns may be achieved, but all this cannot be integrated into a particular pattern without visual aid.

Determination of receptor dominance should be pushed even further back into infancy by devising situations in which infant learning may be analyzed. Older children should also be studied with a view to establishing the hypothesis indicated by this study, namely, that the ability to use kinesthetic cues as the sole guidance in learning a series of coördinated movements that form a definite spatial pattern probably develops with age, instead of retrogressing. Further study should be made as to the part verbalization plays in the above process.

REFERENCES

(1) BERKELEY, GEORGE: An essay towards a new theory of vision. In Berkeley, Essay, principles, dialogues, with selections from other writings. Edited by Mary Whiton Calkins. New York, Charles Scribner's Sons, 1929, pp. 13–98.

(2) BROWN, WARNER: Auditory and visual cues in maze learning. University of California Publications in Psychology, 1932, **5**: 115–122, No. 5.

(3) BROWN, WARNER: Spatial integrations in a human maze. University of California Publications in Psychology, 1932, **5**: 123–134, No. 6.

(4) CARR, HARVEY: The influence of visual guidance in maze learning. J. Exp. Psychol., 1921, **4**: No. 6, 399–417.

(5) CARR, H. A. AND OSBOURN, ELLA B.: Influence of vision in acquiring skill. J. Exp. Psychol., 1922, **5**: 301–311.

(6) CUTSFORTH, THOMAS D.: An analysis of the relationship between tactual and visual perception. Psychol. Rev. Monog. Suppl., 1933, **44**: No. 1, 125–152.

(7) DASHIELL, J. F.: Direction orientation in maze running by the white rat. Comp. Psychol. Monog., 1930, **7**: No. 2.

(8) DENNIS, WAYNE: The sensory control of the white rat in the maze habit. J. Genet. Psychol., 1929, **36**: 59–90.

(9) DESANCTIS, SANTE: Visual apprehension in the maze behavior of normal and feebleminded children. J. Genet. Psychol., 1931, **39**: 463–467.

(10) DORCUS, R. M. AND GRAY, W. L.: The rôle of kinesthesis in retention by rats. J. Comp. Psychol., 1932, **13**: 447–451.

(11) EWERT, HARRY P.: A study of the effect of inverted retinal stimulation upon spatially coördinated behavior. Genetic Psych. Monog., 1930, **7**: Nos. 3 and 4.

(12) HICKS, J. ALLEN, AND RALPH, DOROTHY W.: The effect of practice in tracing the Porteus diamond maze. Child Development, 1931, **11**: 156–8.

(13) JOHNSON, BUFORD J.: Mental growth of children in relation to the rate of growth in bodily development. New York, Dutton, 1925.

(14) HUNTER, WALTER S.: Kinesthetic sensory processes in the white rat. Psychol. Bull., 1918, **15**: 36–7.

(15) HUNTER, WALTER S.: The temporal maze and kinesthetic sensory process in the white rat. Psychobiology, 1920, **2**: 1–17.

(16) HUNTER, WALTER S.: The sensory control of the maze habit in the white rat. J. Genet. Psychol., 1929, **36**: 505–537.

(17) HUNTER, WALTER S.: A further consideration of the sensory control of the maze habit in the white rat. J. Genet. Psychol., 1930, **38**: 3–19.

(18) KNOTTS, JOSEPHINE R. AND MILES, W. R.: The maze learning ability of blind compared with sighted children. J. Genet. Psychol., 1929, **36**: 21–49.

(19) KOCH, HELEN L. AND UFKESS, JEANETTE: A comparative study of stylus maze learning by blind and seeing subjects. J. Exp. Psychol., 1926, **9**: 118–131.

(20) LASHLEY, K. S. AND BALL, J.: Spinal conduction and kinesthetic sensitivity in the maze habit. J. Comp. Psychol., 1929, **9**: 71–106.

(21) LINDLEY, STANLEY B.: The maze learning ability of anosmic and blind anosmic rats. J. Genet. Psychol., 1930, **37**: 245–265.

(22) MACFARLANE, D. A.: The rôle of kinesthesis in maze learning. Univ. of California, Publications in Psych., 1930; **4**: 277–305 (No. 18).

(23) PERRIN, FLEMING ALLEN CLAY: An experimental and introspective study of the human learning process in the maze. Psychol. Monog., 1914, **16**: No. 4.

(24) PETERSON, J. AND ALLISON, L. W.: Effects of visual exposure on the rate and reliability of stylus maze learning. J. Gen. Psychol., 1930, **4**: 36–48.

(25) PYLES, MAJORIE K.: Verbalization as a factor in learning. Child Development, 1932, **3**: 108–113.

(26) RENSHAW, SAMUEL, WHERRY, R. J., AND NEWLIN, J. C.: Cutaneous localization in congenitally blind versus seeing children and adults. J. Genet. Psychol., 1930, **28**: 239–247.

(27) RENSHAW, SAMUEL, AND WHERRY, ROBERT J.: Studies on cutaneous localization. III. The age of onset of ocular dominance. J. Genet. Psychol., 1931, **39**: 493–6.

(28) RICE, CHARLOTTE: The orientation of plane figures as a factor in their perception by children. Child Development, 1930, **1**: 111–143.

(29) RICE, CHARLOTTE: Eye and hand movements in the training of perception. Child Development, 1931, **2**: 30–48.

(30) RICHARDSON, FLORENCE: A study of sensory control in the rat. Psychol. Rev. Monog. Suppl., 1909, **12**: No. 1.

(31) SENDEN, MARIUS VON: Raum-und Gestaltauffassung bei operierten Blindgeborenen vor und nach der Operation. Leipzig, Verlag von Johann Ambrosius Barth, 1932.

(32) STRATTON, GEORGE M.: Vision without inversion of the retinal image. Psychol. Rev., 1897, **4**: 341–360; 463–481.

(33) TWITMYER, EDWARD M.: Visual guidance in motor learning. Am. J. of Psychol., 1931, **43**: 165–187.

(34) WALTON, ALBERT: Visual cues in maze running by the albino rat. J. Genet. Psychol., 1930, **38**: 50–77.

(35) WARDEN, C. J.: The relative economy of various modes of attack in the mastery of a stylus maze. J. Exp. Psychol., 1924, **7**: 243–275.

(36) WATSON, JOHN B.: Kinesthetic and organic sensations: their rôle in the reactions of the white rat to the maze. Psychol. Rev. Monog. Suppl., 1907, **8**: No. 2.

(37) WEAVER, HOMER E., AND STONE, CALVIN P.: The relative ability of blind and normal rats in maze learning. J. Genet. Psychol., 1928, **35**: 157–175.

(38) WOOSTER, MARGARET: Certain factors in the development of a new spatial co-ordination. Psychol. Monog., 1923, **32**: No. 4.

(39) YOUNG, HERMAN H.: Slot maze A. Psychol. Clinic, 1922, **14**: 73–82.

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